

# A Multi-output Transformation Function Approach for Capacity Measurement

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# Why Measure Capacity and Utilization?

- Excess capacity is fairly obvious
- Focus on incentives rather than symptoms

- FAO International Plan of Action
  - U.S. National Plan of Action
- As an aid in prioritizing troubled fisheries
  - Rationalization, buybacks
- Assess effectiveness of policies to curb fishing power
- Legislators and resource managers often need numbers to support actions

# Capacity Measurement Literature

- Extensive literature exists for other industries; models typically rely on duality
  - Facilitates multi-input, multi-output models...but:
- Behavioral assumptions may not be appropriate for many fisheries – especially those with capacity “issues”
- Data requirements are typically greater than that available in U.S. federally managed fisheries

# Result: Use Primal Models

- In a primal context, capacity has been defined as maximum *physical* level of output
  - Excess physical capacity relative to some target TAC may be indicative of the degree of overinvestment
- Efficiency literature looks at potential increases in output (for output-orientation); sort of connotes “capacity”
  - Capacity is found by shifting out efficient frontier to reflect “unrestricted” variable input use

# Are Efficiency Approaches (DEA, SPF) Realistic for Capacity in Fisheries?

- Efficient frontier based on best observed outcomes and vessels in an inherently random industry
  - Weather, luck, varying natural environment
  - May want to use averages for each vessel to cut down outliers
- Non-stochastic approaches may exacerbate this problem
- *Physical* harvesting efficiency may already be necessarily high in many open-access settings
  - Efficiency differences may exist, but may not be reversible in the short run
  - Potential efficiency gains may be more likely in the areas of cost and product quality

# Primal Models w/ no Efficiency Aspects in Multi-species Fisheries

- Production Function
  - Single-output specification valid under:
    - Input non-jointness (separate prod. functions); or
    - Output separability (can aggregate outputs);
  - Both conditions have frequently been rejected in the literature on multi-species fisheries
- Transformation Function
  - Accommodates multi-input, multi-output technologies in an econometric framework

# Benefits of Transformation Function

- Capacity estimates based on customary and usual production, don't incorporate potential efficiency gains
- No fixed proportions assumptions over outputs when computing capacity

## Relative to DEA:

- Accommodates randomness inherent to fisheries
- Facilitates retrieval of production elasticities, statistical tests

## Relative to SPF:

- Has observable LHS variable (unlike SPF distance function)
  - No need to normalize RHS outputs by LHS output
  - Eliminates a source of endogeneity bias
  - Eases interpretability of production elasticities
- No assumptions required for the inefficiency error term

# Model Specification: Generalized Linear Transformation Function (Diewert)

$$Y_1 = \alpha + \sum_{i=1}^K \beta_i z_i^{1/2} + \sum_{i=1}^K \sum_{j=1}^K \gamma_{ij} z_i^{1/2} z_j^{1/2}$$

where  $z = (X, Y_{\neq 1}, \Omega)$ ;

- $X$  includes vessel characteristics, crew size, towing duration, and days at sea
- $Y_{\neq 1}$  includes all outputs except  $Y_1$
- $\Omega$  accounts for other factors (a time trend, stock sizes or CPUE, seasonal or spatial dummies, vessel-specific fixed effects)

# Using the Model: How might input levels and output composition change at capacity?

- Increase inputs that are externally constrained
  - Try to increasing factors of production in a realistic manner
  - Important to consider fishery being examined
  - In many fisheries, increasing fishing days (given crew size, daily fishing duration) is a reasonable approximation
- Examine various assumptions about output composition at capacity

# Input and Output Specifications

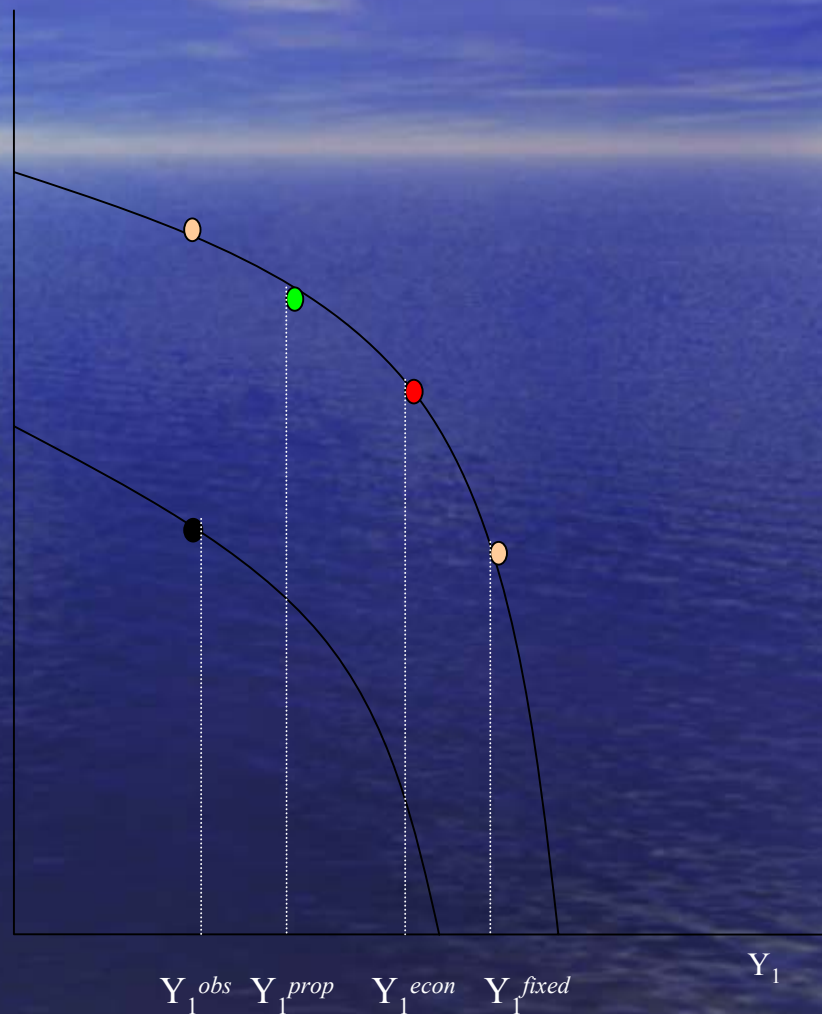
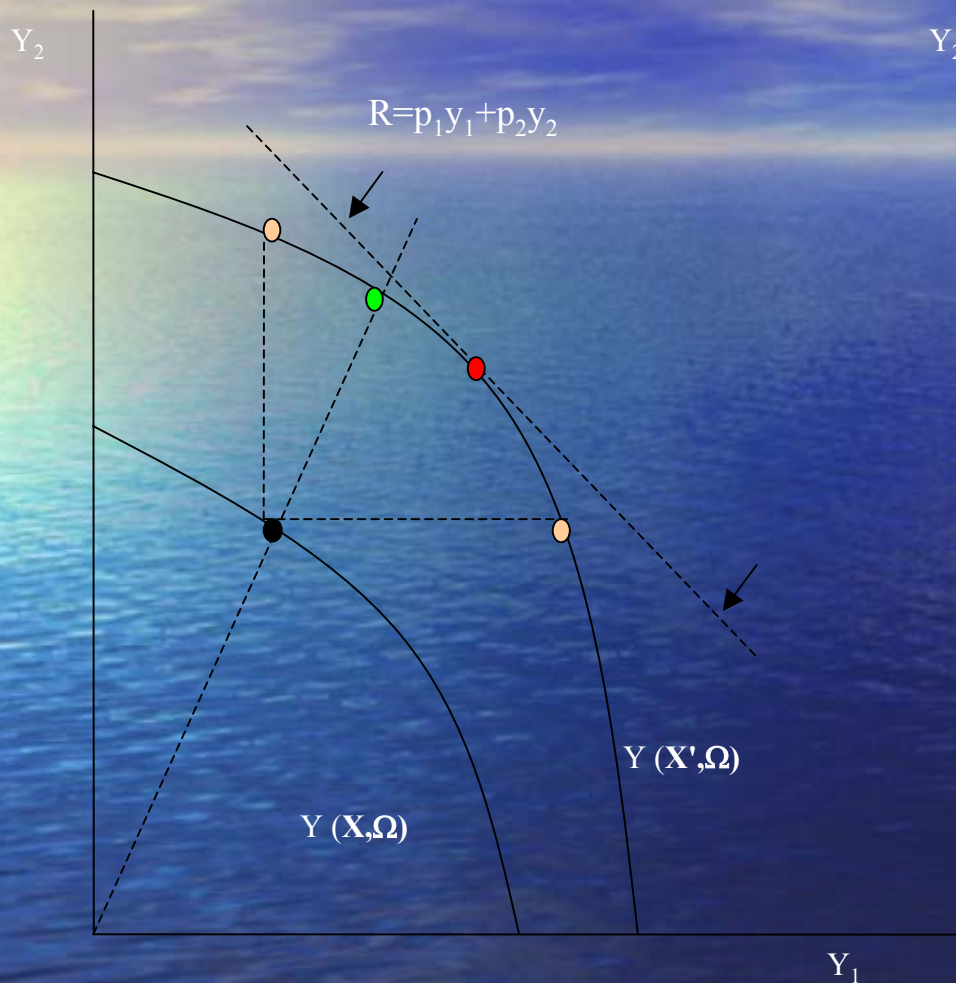
## Inputs:

- 1) Examine a range; or
  - increase fishing days,  $X_{\text{days}}$  by  $\alpha$  percent ( $X_{\text{days}}^\alpha$ )
- 2) Examine marginal product of additional fishing days
  - Solve for  $X_{\text{days}}$  where  $MP = \partial Y_1 / \partial X_{\text{days}} = 0$ ;
  - or where  $VMP = MC_{\text{days}}$  ( $X_{\text{days}}^{MP}$ )

## Outputs:

- 1) increase one output with all others fixed (“*fixed*”)
- 2) fixed proportions among outputs (“*prop*”)
- 3) to an economic optimum;  $MRT_{i,j} = - p_j / p_i$  (“*econ*”)

# Output specifications, graphically:



# Solution Procedure

# of variables examined must = # of equations; all are solved simultaneously

For example, if we allow days fished and two outputs to change at capacity (3 variables), we must have 3 equations to compute these values:

- 1) transformation function evaluated at capacity values of days and outputs ( $X_{\text{days}}^{\text{capacity}}$  and  $Y_2^{\text{capacity}}$ )
- 2) equation defining days fished,  $X_{\text{days}}^{\text{capacity}}$  (for either an  $\alpha$ - or MP-based increase)
- 3) equation defining the relationship between outputs,  $Y_2^{\text{capacity}} = f(Y_1^{\text{capacity}})$

Equations (in addition to fitted transformation function):

For  $X_{\text{days}}$ :

- $\alpha$ -increase:  $X_{\text{days}}^{\text{capacity}} = X_{\text{days}} \cdot (1.\alpha)$
- MP-based increase: find analytic expression for  $X_{\text{days}}^{\text{capacity}}$  where condition holds

For Outputs:

- “*prop*”: define  $Y_2^{\text{capacity}} / Y_2 = Y_1^{\text{capacity}} / Y_1$
- “*econ*”: find analytic expression for  $Y_2^{\text{capacity}}$  where  $\partial Y_1 / \partial Y_2 = - p_2 / p_1$
- “*fixed*”: define  $Y_2^{\text{capacity}} = Y_2$

# Interpreting the Results

- End result is estimates of capacity output for each species, number of days fished
- Capacity utilization ratios may be constructed
  - Allowing output composition to change in “*econ*” allows CU ratios to exceed 1 ( as in dual models)
    - Output adjustment may imply current production of one species may exceed revenue-maximizing levels
- Assumptions about other inputs, outputs may be examined...

# Input and Output Biases

- Input biases indicate whether input composition is likely to change at capacity
  - Does slope of input isoquants  $((\partial Y_1 / \partial X_1) / (\partial Y_1 / \partial X_2))$  change as output expands?
  - Can also compute  $\varepsilon_{MP_{X_{Crew}}, X_{Days}} = \partial \ln(MP_{X_{Crew}}) / \partial \ln X_{Days}$  to see if use of particular inputs may increase at capacity
- Output biases bear similarly on output composition
  - Does output tradeoff (MRT) change as days fished changes?
  - Compute  $\partial \ln(\text{MRT}) / \partial \ln(X_{\text{days}})$
- This information can guide or refine the assumptions over how input and output use may change

# Limitations and Issues

- Static, short-run model; doesn't specify long-run target level of investment
- Doesn't explicitly include biological interactions
  - However, stock levels or CPUE can be decreased to reflect a movement toward capacity
    - Size of fleet under study may determine size of impact
- Primal models have potential endogeneity bias
  - Okay under  $E(\Pi)$  maximization (Zellner et. al)
  - Limitation shared by SPF model
- Doesn't account for latent vessels

# Conclusion

- Model accommodates multi-input, multi-output fisheries with commonly available data
- Fishing capacity is estimated relative to customary practices
  - Important when “environmental” data not available or outcomes of the best boats are unlikely to be achievable on a regular basis
  - Capacity estimates don’t embody efficiency increases (just effort increases)
- Fixed proportions in outputs can be relaxed
  - Allows for a bit more “economics” in a primal setting